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Education, Science and Technology
Research in Eastern Africa

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Introduction :

A hundred years have elapsed since the West Indian scholar, Edward Blyden, urged Liberian undergraduates in his inaugural address at Liberia College to concentrate on a liberal and moral education, leaving the realms of science, technology and industry to the Europeans and Americans. Today, nothing could be a higher priority than education in science and technology - to judge from the discussions by African Ministers of Education in their June 1982 meeting at Harare, Zimbabwe.[1] There are many pointers to this priority in East Africa. Ordinary Kenyans across the country have been prepared to build with their own funds a whole series of institutes of science and technology. Almost the only group of male Tanzanian high school students allowed direct access to the University of Dar es Salaam are the engineering and medical students; all others must spend two years working before they are eligible. Both countries are actively contemplating a second more technologically-oriented university, despite their economic crises. Both also, on the application sides of technology, have an increasing number of bodies directly concerned with advice, support and research upon agricultural, industrial and domestic technologies.

Although the current is running strongly in favour of technological education and its application, major problems still seem to stand in the way. Kenya's achievement in science and maths reached an all-time low in 1981, with 75% of 'O' level candidates completely failing maths. Some of this might be attributed to the dramatic speed of secondary school expansion in the last twenty years, but Tanzania has held its secondary school sector to a tenth of the size of Kenya, and still has encountered major problems in science and maths. In the training sphere there are still very fundamental worries about the role of whole subsectors of the national training and education enterprise. Frequently these relate to the changing interactions between education levels and employment (or unemployment). Such changes are constantly fueled by the relative speeds of education expansion and relative sluggishness of labour market growth. In Kenya, for instance, the mood

1. UNESCO, Preparatory meeting of experts for the Conference of Ministers of Education in African member states, Harare (Zimbabwe) June 1982.

is beginning to swing against 'A' levels (for a variety of reasons to which we will return); at the same time, the technical schools are once again under fire, and it looks on balance as if the technical secondary school may soon no longer exist.

Over the border, in Tanzania, 'A' levels are unquestioned, but the whole fifteen year policy of protecting the fragile economy against the preparation and employment of too many secondary school leavers looks like it is on the point of being abandoned. Secondary schools at minimum cost (to the state) and possibly of very variable quality seem all set to mushroom. Nothing very remarkable has happened in the labour market to underpin the expansion; it appears almost as an unanticipated consequence of encouraging universal primary education. But with school expansion, there will cease one of the last examples of the secondary school student as a 'manpower' category, - someone the state had earmarked for employment in the formal labour market.

In industry and agriculture, there are clearly very different sets of problems in Tanzania, from Kenya, and in Zambia from Ethiopia. In common, however, is some sense that, partial import substitution having taken place, there should be a next step. In what sphere does the region have a comparative advantage? What is the role of higher technological education in carving out any niche? Technological dependence is only too evident as industries slow down and even halt for lack of foreign exchange for spare parts or critical imports. In many cases the component could be made in the country concerned, and it is presumably partly a failure to apply science that is accounting for it. Indicative of this belief in the education aspect of technological independence is the Institute for Production Innovation at Dar es Salaam's Faculty of Engineering. This is not really concerned with innovation, but rather with demonstrating to companies, long accustomed to import but now without the foreign exchange to do so, that the item can be made in Tanzania.

Uganda and Tanzania are both beset by aspects of the foreign exchange problem, and consequently with the need for a greater degree of innovation in existing industries than has been common in the past. To some extent, the economic crisis produces for the formal sector of the economy many of the features of the informal sector. This "informalisation" of the formal sector is an area that needs close attention; sometimes the absence of regular routes for import of spare parts does not so much encourage entrepreneurship but rather a whole alternative market in which almost everything is available - at a price. In an economy of shortage, therefore, it is by no means easy to follow through the logic of indigenous innovation and manufacture. The informal sector virtues of improvisation and self reliance clearly ought to be at a premium, but in the short term it is more profitable to acquire the foreign components at whatever cost and pass the increase on to the consumer.

Prolonged foreign exchange crises can act like sanctions to encourage local ingenuity in substituting for what was imported. Evidently, this does not necessarily happen. The mix of political and social factors introduced is complex, but clearly one key strand is the scientific and technological capacity of the country concerned. To what extent has the formation of scientists and technologists encouraged a readiness and capacity to experiment? Is it even conceivable that the period of education exposure could on its own predispose people in this direction? Only too often, the education and training systems are themselves adversely affected by economic pressure in ways that make them even less likely to respond to the needs of the hour. In resource-poor countries, it is common for technical schools, polytechnics and engineering faculties themselves to be hard hit by shortages. The first shortage is of materials (steel, wood, plastics, polymers) and of money to maintain the workshops, and their machines. The result? A tendency for technological education to become more theoretical and less practical during a time of economic stringency, and the likelihood that the students acquire less preparation for the rigours of production in scarcity conditions.

One important task throughout the region would be to gain some perspective on the changing correspondence between education and work in these increasingly common economic conditions. To what extent have the education and training systems of the ex-British possessions been positively altered by the twenty odd years of independence? Quantitatively, there is obviously an enormous difference in coverage between the later colonial period and the early 1980's. But qualitatively what adjustments have there been to fit education better into the current technological environment? Is there any evidence that educational planning is carried on with an awareness of the issues in science and technology planning? To an extent both educational and technological planning are reactive processes. Those most concerned with "planning" in these fields can seldom take the initiative, but instead follow on initiatives taken by government, and agencies, or the private sector. A decision is taken to scrap 'A' levels or to build an enormous paper mill. Education and technology analysts then proceed to calculate the consequence. However, despite this relatively subordinate role in the planning process, there is an accumulation of experience that does increasingly inform parts of the decision-making process, and it is important accordingly to chart something of this received wisdom.

Intimately connected with the state of educational and technology planning is the rather fluid situation of those institutions intended to train people for scientific, technological and technical careers. The older hierarchies of status imported from Europe are not particularly sacrosanct and the boundary conditions amongst occupations seem much less fixed. The urge for access to further education has frequently converted an institution intended to be terminal into a staging post for the next level. Craftsman schools get used by technicians-in-the-making, and polytechnics as alternative routes to higher education. Largely responsible for this blurring of distinctions on the vocational-technical-technological side is the relatively small size of all post-primary education, and the consequent sense amongst students that they are part of a numerically very restricted sector. If a student has reached a tiny 'National Youth Service', or one of the handful of Vocational Training Institutes, it is more an encouragement to persevere than it is to settle and become a craftsman at that level.

Also driving the aspirations of those in the few small formal training institutions is their awareness that outside in the 'informal sector', very large numbers of people are acquiring skills directly on the job.

There is the greatest possible contrast between learning automechanics in a government trade school or technical secondary school, and learning it on the job, or under it. This unplanned sector needs to be borne in mind both by education and technology planners. As a disseminator of skill and technology, it is a powerful ally, and its 'dynamism' helps to explain many of the apparant failures of initiative in the formal sector.

Of the illustrations which follow, the majority are derived from Kenya and Tanzania. The intention in thus focussing on one or two countries was to give some sense of the range of issues that could be expected to be found also in neighbouring countries, albeit in somewhat different forms. This is by no means an exhaustive list of issues that emerged in the fields of technology and education, but it may serve as some guide for discussion and analysis of the interaction between these two fields.

1. Science, Technology, Education and Development

One of the main thrusts of the Harare meeting of African Ministers of Education in 1982 was to assert a link between science education at all levels and the achievement of scientific and technological mastery. Northern domination of science and technology had been only too evident during the decades of colonial education. In the 1960s there had been much greater assimilation of African science syllabuses and programmes to those of their earlier metropolitan powers, but to judge from the tone of the Harare recommendations, this rather limited transfer of educational curricula and technology had not had a major impact on Africans environmental problems, nor on the underdevelopment of industry and agriculture. During the years of rapid post independence expansion the emphasis had been on quantitative growth; insufficient attention had been paid to the quality of the transferred materials. As a result, these early investments in new science and new maths do not appear to have paid off. The spin-off expected from science does not seem to have taken place.

The Harare judgement about this situation is quite clear: much more scientific and technological education is necessary and must henceforth be more applied if Africa is to break out of its current technological dependency. The language is strong and the logic straightforward:

> Science and technology form the basis of industrialisation; the fact that they can be used as such effective instruments and vehicles of development means that the entire population must be associated with scientific and technological advance, that they must be given pride of place in education ... There was unanimous agreement that it was high time action was taken on all matters concerning the extension and improvement of science and technology teaching at all levels, with a view to mastering and modifying imported technology, putting an end to scientific and technological dependence, and finding solutions to the most pressing problems of development. [1]

1. UNESCO: Preparatory meeting of experts for the Conference of Ministers of Education (HARARE, 21-25 June 1982) item 5.4.

This view of science and technology education as a powerful set of levers that can be applied directly to wider problems of society is not unique to Africa. Nor is it uncommon to criticise science education itself for accentuating the pupils' belief that scientific discoveries all seem to take place elsewhere rather than in their own country.

> School children learn of the accomplishment and impact of science in other countries ... but they learn virtually nothing about the impact of science in their own country. And the reason is that they are not being taught such matters. [1]

This could have been written of many of the countries of East and Central Africa, just as twenty years ago it could have been said of many of the standard history text books in Africa which concentrated upon European achievements, voyages and discoveries. In fact the quotation comes from an August 1982 critique of Canadian science education from the Science Council. And it would not be difficult to find even in the USA major worries about the quality and extent of science teaching, and the nation's threatened supremacy in many new technologies.[2]

Despite evidence of concern about science education in industrialised countries, many East and Central African nations expect even more from science and technology investment if the gap between North and South is to be narrowed at all. Just to prevent the gap widening even further they calculate they will require very major investments across the board: more techologically oriented universities, more local production of science equipment, more science and technology research structures.

1. Science Council of Canada. Science Education in Canadian Schools. (Aug. 1982, draft, p.4).

2. The word 'America' could have been substituted for that of many countries in the following excerpt: "Fully half of America's science and mathematics teachers were teaching with emergency certificates in 1981-82. The nationwide shortage of qualified teachers is likely to persist as long as college students with a talent for science and mathematics can expect to earn nearly twice as much in business as they would in teaching. (Herald Tribune - Oct. 11th, 1982)

The nations of East, Central and Southern Africa have a dimension of their attitude to science and technology which is, however, historically and politically very different to that of Canada or U.K. towards the United States. The political domination of the entire region on racial lines has ended, with the exception of South Africa, but it is still very evident to many local scholars and policymakers that there is a continuing supremacy of whites (and to some extent resident Asians) in virtually all fields of scientific inquiry. The patterns of Africanisation of the civil service and the universities have thus far resulted in much higher levels of African staff in arts, social science and law faculties, and in the administrative branches of the civil service than in the science, agriculture, veterinary and medical faculties, and in the technical and research branches of the various Ministries. The polytechnics are another sphere where localisation has moved very slowly indeed.

As a consequence, there has been a tendency for whites to continue to be in the forefront of research and publishing within East and Central Africa, in the very fields where Africa might be expected to have an international comparative advantage. Thus in wild life research, range management, agro-forestry, thermal and solar energy applications, appropriate agricultural technologies, palaeontology, and archaeology, very significant contributions continue to be made by non-Africans.

This skewing of the scientific research environment along what used to be called the colour line is most conspicuous in South Africa, but in many other countries of the region twenty years of independence have little altered the division of high technological labour along lines of colour. The conquest of scientific frontiers by African researchers has therefore got a particular edge to it beyond the merely technological, as can be seen in a recent comment from Michael Sefali, director of the Institute of Southern African Studies. Indigenising science and technology implies simultaneous conscientisation of scientists about the anatomy of disadvantage:

> Undoubtedly the cardinal task of scientific research is to help build scientific technological base for the socio-economic development of the liberated zone of Southern Africa. Science must be an active agent of change and development in Southern Africa. There is no question of science for the sake of science. This is the practical calling of policy-related and development-oriented scientific research in contemporary Southern Africa, not merely to interpret the region but to take an active part in its revolutionary transformation for the good of its people. [1]

2. The Realities of Science Education in Eastern Africa

The rhetoric about the potential of scientific and technical investment in school and college is flying high at the very point when really major worries are being raised about the achievement of schools, and to a lesser extent colleges. Reference has already been made to mathematics scores in Kenya, and there is no particular reason to believe that Kenya's results are likely to be very out of line with other countries in the region, except that its secondary school expansion has been more rapid than most. Indeed, unlike many neighbours, Kenya actually has a whole college (Kenya Science Teachers College) dedicated to the production of specialist teachers. It has also an examinations research unit which over ten years has had a marked impact on awareness of primary science and maths problems, and is now turning its attention to secondary schools. Even so, science, maths and technology education clearly stand at some kind of crisis point. Reasons differ somewhat from country to country, but amongst the most central would be:

- Over-rapid run-down of expatriate science teachers and lecturers as external aid budgets were cut back from the mid 1970s.
- textbooks imported, hence continuing drain on foreign exchange.
- science equipment still largely imported and now in short supply.
- low general level of technological and scientific 'literacy' amongst parents and the wider community.
- curricula ill-adapted to present student populations, but also too frequently changed.
- insufficient attention to the quality of science achievement in school, polytechnic and university.

1. M. Sefali, 'Research and technology in Southern Africa: Priorities and the need for coordination of research efforts', <u>Workshop on Research Priorities</u>, 23-27 November, 81 National University of Lesotho, p. 8.

The state of research on the complex interactions of school and college science and technology on the one had and industrial and agricultural applications on the other is so little developed that it is difficult to be certain about what are the most critical deficits in the science training system. Indeed research on science achievement and attitudes to science have had so very little attention that it is hard even to be certain how serious the science training situation really is. There are, however, a number of pointers to potentially valuable work.

a. <u>Science curriculum analysis, further training, and different labour markets</u>

In several countries of Eastern Africa, the science syllabuses are based on science for continuation to tertiary education. They constitute varieties of 'O' level science derived principally from the U.K. Designed originally in U.K. for only a small proportion of the age group that would take 'O' levels, they were transferred to small highly selective school systems of the mid to late 1960s, staffed largely on the science side by expatriates. The 'fit', therefore, originally was not far out. In some settings, 'discovery' science in the Nuffield mode even then made large demands on the supply of equipment and of good teachers. But once a larger proportion of the age group began to come into the secondary systems, the unsuitability of these syllabuses (or watered-down versions of them) became more apparent. In a sense, some of these countries by the accident of the timing of Independence bought into 'elite' science because that was in vogue at the time. Since then the West has moved rapidly to diversify science provision for the less able, and for those not proceeding to further education, and has begun also to move into a new series of science-for-society, science-for-life courses, looking at major themes of energy, the environment etc. It now looks as if resource constraints may well make it difficult for some developing countries to maintain the momentum of curriculum change set by the West. So, inappropriate though the transferred technology may be, some countries may have to live with what was first imported and modify it as best they can.

In designing any major modification, however, there is an anxiety to be much clearer about the likely relationships between science skills in school and different kinds of further education and work environment. Although the bulk of the early 1960s science streams might legitimately aspire to further training or education, and then a modern sector job, the cohort sitting 'O' levels in the early 1980s is perhaps ten times larger, while the job market has only grown by a fraction. (6,000 took Form Four 'O' levels in Kenya just after Independence in 1964; in 1982 there were 90,000!) Syllabuses haven't begun to come to terms with the inevitable switch of students away from science-for-senior-secondary towards science-for-self-employment. Questions are, however, just beginning to be asked about what is likely to be the impact of studying science for four years in a self-help secondary school without a lab, with no equipment, few text books and with teachers often inadequately trained.

The condition of science and maths in some very ordinary rural secondary schools is doubtless in a different world from science teaching in the best schools in the national capital. But it could be argued that continued expansion will make the former much more representative of the national norm than the latter. Hence it is the quality of scientific life in these thousands of increasingly ordinary schools that must be set against the inspirational rhetoric of Harare. A starting point must be a clearer view of what skills and attitudes are being currently absorbed.[1]

b. <u>New relations between science, maths, technology and the labour market</u>
It is a relatively recent development that science education in East Africa should begin to look outside the school at the relevance of existing skill levels to the types of work available. Traditionally, this concern about work outcome was restricted to students taking technical or vocational education emphases, and it was mainly produced by a worry about the cost of offering these options if students were not affected by them. However, as vocational subjects were low down

1. See the questions raised in a paper by the Kenya National Examination Council in 1982: "How appropriate is science education at the Kenya Certificate of Education level to the needs of Kenya in the 1980s?"

the status hierachy in most schools, studies examining their relation to work often ran into difficulties of estimating how much the students had learnt in the first place. Students were said not to avail themselves of vocational opportunities in later life: but had they even applied themselves to these options in school?

It was quite a different matter with science. This has for almost two decades been the premier subject group, and it has been almost impossible not to do science and maths, if a student was perceived to be bright. A widespread informal streaming by ability produced science streams and science 'A' level schools versus Arts streams and schools. Schools allowed to offer Physics, Chemistry and Maths at Form V and VI were assumed to be superior in Tanzania, for example, and there were similar policies in many other countries. Hence the new interest in asking about the impact of science on work and society is likely to be a very different question from those asked of vocational students. For one thing, as we have mentioned, there is an interest in the transformational potential of science. Not just whether students have ended up in vocational jobs, but whether they are using their science to apply to and modify their environment. There has been very little experience of investigating this kind of question, either for school science impact or for university, or polytechnic, but institutions are beginning to pose the question, and are casting about for a way to estimate the consequences of science investment.[1] It is clear that the interest is not simply in numbers of people occupied and employed in what may loosely be termed science-using jobs, but much more what advantage a science background may afford in actually doing the job. It is obviously not particularly important how much school or college science is remembered or even utilised, but rather how scientific methods are deployed in ways that make some difference to the enterprise in hand.

This is a tall order, but it is one that is central to the spirit of the Harare declaration. If the North-South science and technology gap is not to widen further, then active application of science will have to become more commonplace. Which in turn relates back to the way

1. See draft note by the Education Research Bureau, Kenyatta University College: "Education, technology and employment: the Kenya case." Mimeo 1982.

science is taught and absorbed. There is, as we have said, likely to be a decreasing range of choice for many countries in the type of science they can teach. With school expansion, teacher shortage and equipment deficits, blackboard science is almost certain to push out various kinds of discovery science predicated upon labs and equipment. A retreat from too Jesuitical a belief in discovery science through labs may not be altogether a bad thing. Indeed a recent review of evidence on the role of the science laboratory has suggested amongst much else: 'Students should not use many valuable hours in the laboratory collecting and manipulating data to "discover" principles that could be presented by the teacher or read in a book in a matter of minutes.' [1]

Another area of East African education where researchers are looking anew at relationships between scientific and technical curricula and the labour market is that of 'diversified' schooling, a term denoting a number of biases in the ordinary secondary school. The most common have been agricultural science, machine shop, woodwork, electrical, and home science. None of these has been intended to be vocational or prevocational but merely to orient students to certain aspects of the world of work. Over the last fifteen years a good deal of external assistance has gone into this diversification of ordinary academic secondary schools in many developing countries; workshops have been built, equipment installed, school farms developed. But like the problem of evaluating the post-school impact of taking science, it has proved difficult to assess whether diversified curricula are having the desired effect on student attitudes. In the case of students who do not go on to university, how can a Ministery of Education judge the success of a non-vocational programme of this sort? Not by salary levels, certainly, and not by whether they have a job related to the programme taken in school. Possibly, students should retain and apply in their own lives (if not in their work) some of the information and practical skills acquired. But designing measures to verify this kind of impact is notoriously difficult.

1. Wadi Haddad, Role and educational effects of practical activity in science education (World Bank, draft discussion paper, 1981 p. 51.).

It is, nevertheless, an area that is of great current concern to governments in the region. Tanzania is currently collaborating in a World Bank project examining outcomes of its version of diversified schooling, whose preliminary results should be available at the beginning of 1983. Kenya has sought to compare the results of their industrial arts versus their technical schools, but the research has not so far been completed. To many policy people, diversified schools are something of an anomaly: they are too expensive to allow conversion of all secondary schools to this mode,[1] but insufficiently vocational to be judged by criteria of skill gained and job entered.

This underlines a more general problem about viewing schools in poorer countries as vehicles for science, technology and education for development. Social engineering via the curriculum is expensive, and frequently the innovation can only be applied to a fraction of the schools. (For example, in Kenya not many more than 30 out of the 1500 secondary schools qualify as properly diversified towards industrial arts.) In such a setting, drawing conclusions about the labour market impact of a particular curriculum is a hazardous undertaking, however important it may be to judge the value of an educational investment.

Sometimes even before an innovation has spread nationally, a new approach begins to be recommended internationally. The developing country has to consider whether to move with the times, or stick with what it has already. This is particularly likely to happen in science, given the speed with which scientific knowledge and its application is changing. We have noted earlier the problem faced by countries who bought into discovery science for the upper ability range, and who are now concerned with science for all. Equally the proposals of the Commonwealth Secretariat to develop core course materials drawing on science, maths and technology present a new challenge. In the light of countries' quests for

1. Tanzania's diversified schools are much more widespread and a much greater time allocation is given to their four biases, whether agriculture, technical, commercial or home economics.

a less elite science, an effort to seek out the connections amongst three areas that have been rather rigidly set apart makes very good sense on paper. The application of insights from science, technology and maths to subjects like rural energy, pollution etc would be challenging. It suggests a level of integration of different disciplines and their application that almost certainly is not achieved with the ordinary school leaver. But the proposal is also a good example of where an eminently sensible development-oriented initiative will face disciplinary hostilities, not least the view that technology education is a lower order of life than science and maths.

There are, therefore, major in-school obstacles (reflecting wider societal values upon knowledge of different sorts) that may stand in the way of attempts to produce 'development science', drawing upon maths, and rural and urban technologies. For one thing, the 'A' level orientation of much schooling in East and Central Africa and its link to single subject university disciplines directly undermines moves towards integration of science. It is for this reason important to analyse the consequences of abandoning 'A' levels, as Kenya is currently exploring. With their rigid distinctions between science 'A' levels and Arts, these courses have certainly helped to suggest that the only reason to do science in school was to do science in university. On the other hand, removing the 'A' level segment will not magically remove the university backwash effect, nor convert the science curricula of Kenya into rugged developmental courses.

These several comments on school science and technology policy raise more questions than they provide answers, but the following are some areas where researchers are beginning to focus:

- Analysing impact of existing science knowledge scattered across the curriculum, especially its effect on ordinary secondary school leavers.
- Rethinking science and technology implications of traditional distinctions between subjects, and between types of school.
- In particular, reviewing technical and vocational education from a science policy perspective.

- In relation to the idealism of Harare,[1] examining precisely how the realities of school science could contribute to the decrease of technological dependency, and the growth of scientific literacy.
- Evaluating school skills and attitudes towards science with work opportunities in relatively dependent economies.
- Continuing to worry about the allegedly very low achievement in science and maths, which may threaten many of these new aspirations and innovations. Hence some interest in cross-national comparison of achievement in science.[2]

3. Engineering Education and Technological Capability in East Africa

Whatever the hopes about using the schools to diffuse scientific literacy, and to democratise understanding of scientific methods applied to development problems, there remains a need for local leadership at a higher level of technological capacity. For many countries the repository of their hopes is the engineering faculty of the national university, and to a lesser extent the faculties of agriculture and medicine. Engineering attracts many of the most talented students in the countries of East and Central Africa. It offers apparently the opportunity to apply scientific principles to the improvement of rural and urban technologies, as well as to make judgements about the appropriateness of new technologies. The engineer stands at the top of a pyramid of technicians and skilled labour, and does so in a variety of different settings from private industry, to national or parastatal enterprises, to research and development centres. Not surprisingly, African engineering students and graduates have come to be the centre of much debate. They are the focus of many discussions about technological self-reliance, indigenous technological capability, and the potential for local adaptation of imported technology. In addition in Eastern Africa, we have mentioned the difficulty of even discussing their role without encountering the comparison with expatriate engineers in Eastern Africa, or with metropolitan standards of engineering.

1. See also UNESCO, International Congress in Science and Technology Education and National Development, Paris 23 Nov - 2 Dec 1981.

2. Several Eastern African countries want to participate in the IEA's second science study, now getting underway, - Tanzania, Zimbabwe, Botswana and Swaziland.

Certainly the other prestige faculties of medicine and law do not have imposed on them to the same extent the additional burden of altering the local technological advantage of the advanced countries.

The African historian or linguist, for example, may find a great deal of 'Northern' expertise on his own discipline, and may have tough competition in publishing in the prestige journals on African history or language, many of which are edited and published outside Africa. But no one now doubts that it is possible to be an African historian in Africa. In engineering, on the other hand, one of the research debates at the moment in Kenya and Tanzania is the extent to which it is even possible fully to exercise the profession of engineer. Given the emphasis in the Northern industrialised countries on engineering as a profession requiring original design skills, being intellectually varied, and not concerned with routine operations, it has been suggested that sufficient variety of production is not available in many of the East African economies. In addition, because of their equipment having been designed and developed abroad, it may prove cheaper for enterprises occasionally to call upon the services of the foreign technology suppliers than to employ a fulltime resident engineer. The position has been put very baldly by one expatriate researcher, with particular reference to electrical and mechanical engineers in Kenya:

> In view of the generally low level of engineering knowledge required to satisfactorily undertake the latter tasks* in the majority of industrial enterprises in Kenya, engineering graduates are therefore mainly employed as managers-cum-technicians rather than as professional engineers *per se*.[1]

Equally critical comments have been made by Tanzanians of the difficulty of functioning as a fully fledged engineer in many of Tanzania's parastatal concerns. Indeed, both Kenya and Tanzania's engineering education sectors have attracted major studies by scholars (Bennell for Kenya,

* i.e. routine and major maintenance and repair and production activities.

1. Bennell P. 'A quantitative Assessment of the utilisation of engineering manpower in Kenya', IDS working paper no. 381, May 1981, IDS, Nairobi p.15.

and von Mitschke-Collande for Tanzania).[1] They provide a useful starting point for many of the other related policy research issues.

(i) Under-utilisation of engineering skills

Clearly a major issue for the faculties of engineering in Eastern Africa is the alleged under-utilisation of engineering qualifications. A lack of opportunity to display design skills can point to a very complex situation. It may be caused by the technological dependency of many firms in East Africa; it may also be related in part to the training experienced in university, or to the lack of an adequate post-university internship system. The five or six years needed to turn the engineering qualification into engineering experience is notoriously difficult to arrange, not just because of the limited range of industry, but also because of the mobility and promotion of young engineers. Behind the simple non-registration of many university degree holders as members of the national institution of engineers may lie a very complicated reality, but one which may throw light on the formation of experienced engineers in the region. Much more needs to be known of the patterns of experience acquisition in different enterprises before one can be certain about the significance of more or less routine work, or more or less opportunity for design. There may, for example, be more scope in East Africa for 'original' design in civil engineering than in mechanical engineering,[2] but it may be difficult to compare a young civil engineer working on a series of one-off-jobs, with a mechanical engineer entering the Kenya Railways or TAZARA* for a life time. The former may appear to be doing more design work, the latter more diagnostic and maintenance activity. But is it really possible to compare their separate contribution to the growth of indigenous technological self reliance? Or take again the engineers attached to a multinational parastatal. They may be involved in/

* The Tanzania-Zambian Railway Authority

1. P. von Mitschke-Collande, Transfer and Development of Technology: Industrialization and Engineering Structure in Tanzania. Hamburg, 1980.

2. Bennell P, 'The Utilisation of Professional engineering skills in Kenya', International seminar on Indigenous Technological Capability, Centre of Africa Studies, Edinburgh University, May 1982.

in some minor modification and adaptation of the imported production machinery, and in the engineering workshop attached to the enterprise they may oversee the production of some spare parts which may earlier have been imported. But basically they act as production engineers, maintaining imported plant, and making technology choices about new plant.

These various engineers may or may not be underemployed, depending on the volume of business and demand; they all work in some way with systems that have been developed outside E. Africa, and which cannot currently be produced locally. Some may be using more of their university knowledge than others, and doing more design work, but what could they reasonably be expected to do as engineers that they are not currently doing? Or, more broadly, in what way might they as engineers be more engaged in activities that would reduce technological dependency? More analysis is probably needed over time of engineering careers in Eastern Africa in order to sort out whether under-utilisation is really a fair term to use. Also the relationships between university training and training on the job thereafter have not been thoroughly examined. Developing measures satisfactorily to look at engineering training is likely to prove as complex as measures estimating utilisation of school science insights. At the moment, however, researchers seem to be interested in teasing out through case studies and other methods the processes of acquisition, utilisation and non-utilisation of engineering capacity.

(ii) East Africa's comparative advantage

While reserving judgement about degrees of engineering utilisation and design work, are there areas where East African engineers (or research scientists) can be breaking new ground? This is obviously a question that exercises national councils of science and technology, and also affects faculties of engineering and science. There is an emphasis in engineering faculties on project work and innovation, as there is on designing machinery to test their projects. But in the relatively underdeveloped industrial setting, where can applied research make a difference?

Many African researchers are frankly dubious about making any breakthroughs related to the technologies imported into the industrial area. In the field of appropriate or intermediate technologies, there seems at first glance to be much more scope, at least for locally significant breakthroughs. This potential will need to be examined rather carefully, however, if it is not to become a blind alley.

Appropriate technology engineering can include the improvement of existing village technologies (transport, heating, light, building materials) or the introduction of new technologies (e.g. using solar, biogas and wind). Again, many East Africans doubt that any breakthrough in the new technologies will come from the region, although the scope for local utilisation appears to be high. However, international funds from the Commonwealth, the United States, multilateral donors and European bilaterals are now quite widely available for work on renewable energy, water pumps, solar applications, agro-forestry. Hence, a good deal of activity is now beginning to be visible in appropriate technology engineering. The mode may be seen by looking at the improvements of the humble round charcoal cooking stove (*Jiko*, in Swahili)

In the last three years there has almost been an outbreak of 'jikomania' in Kenya. The existing stove is admittedly not fuel-efficient, and there has therefore been a lot of interest in improving its design and efficiency. Several agencies have become involved, sponsoring particular new models. Considerable ingenuity in design has led to a burgeoning of new forms, each identified with a particular pressure group. At least one African engineer has been significantly involved, and one of the new designs is his. But it might appear that almost too much 'energy' is being poured into this single item. It would perhaps be worth analysing for this and other local technologies the process and politics of this type of technological change. The research process is relatively very cheap; related research on charcoal production can be linked to it, and both in turn can be linked to research programmes on agro-forestry. Hence the *jiko* research can appeal not only as improving a technology used by the mass of urban and many rural families, but it also has backward linkages to charcoal kilns and tree planting.[1] Kenya clearly has a comparative advantage in jiko improvement technology, in a way that they do not have with solar or wind applications, but it is a field in which there is no external competition, and little application of advanced technology. By contrast, the fuel-saving technologies of Northern Europe, America and Japan are seeing the application of microelectronics to solar panels and conventional boilers, and precision engineering of woodstoves, with massive research into solar technology.

In short, these local technologies are attractive to donors, have benefits to large numbers of the population, are relatively cheap; and offer a good chance of noticeable improvement. They are still perceived, however, to be technologies recommended by whites for Africa, and even to be areas where expatriates in Africa frequently have the edge on local researchers. In addition, they do not address the technology gap between North and South in any dramatic way, and to this extent have been criticised in some African engineering circles.[2] Nevertheless, they do offer a source for low cost student projects during their engineering courses, and more important an opportunity for a very low cost set of relevant experiments with wind, water, fuel and sun that could become commonplace in school science.

(iii) Learning engineering in Eastern Africa

In view of the debates about the under-utilisation of engineering skills and the status of the engineer in Eastern Africa, it is vital to examine how engineering (and science) is acquired in university. One rather common view is that the university has to compensate for for the low level of technological literacy in its incoming engineering student. As we have said, these students are frequently the most academically talented in the high schools, but have had little personal exposure to the innards of either new or old technologies. Scrap and junk are for obvious reasons so differently valued in rich and poor

1. See the Ministry of Energy (Kenya), Renewable Energy Development Programme sponsored by USAID and contracted to Energy Development International.

2. See M.O.Chijioke, 'The higher educational resources for industry' unpublished paper, African Institute for Higher Technical Training and Research, Nairobi 1981(?)

countries that maintaining a hundred dollar car is not an East African student's leisure time experience, nor is building up computer components into working models. University is still generally preceded by no less than six years of boarding secondary school, often in rural areas. There may well, therefore, be some deficit in technical literacy, despite very good results in the 'A' level science exams. It is possibly for this reason that Dar es Salaam's engineering school devotes no less than half the first year to elementary experience in technical materials, processes and handling of equipment and machinery. Small group experience is organised through six workshops: Carpentry: Building: sheetmetal and bench work; welding, forging and casting; machine tools; and electrical.[1] In Nairobi also there is active concern about combating basic background weaknesses in materials and machine handling, but doing so in ways that do not divert attention from offering a syllabus on a par with engineering education in the UK and elsewhere.[2] At the moment, less is known about the engineering education in Makerere, Kampala, for example, but it may well have been difficult for the university to maintain the element of hands-on practical experience during the time of Amin. The lack of spare parts and materials for teaching and testing can either lead to greater self reliance and industrial innovation or to an increasing theoretisation of the engineer's preparation. In Addis Ababa, also, as recently as August 1982 a major seminar was held with the Faculties of Science, and of Technology, reviewing the standard of graduates in these fields, and emphasising concurrently the critical importance of science and technology for hastening the country's economic progress.

1. Brochure: Faculty of Engineering, DSM. 1979.

2. Tim Bessell, 'Observations on engineering education in developing countries', unpublished paper, Faculty of Engineering, Nairobi University, 1982.

There is constantly, therefore, for some universities, a tension between the aspirations and the rhetoric of engineering for transformation, and "the promotion of endogenous development" on the one hand,[1] and the realities of engineering training in resource-poor conditions. Whatever the truth about the lack of students' practical exposure to workaday technologies, faculties may have to compensate for that, at the same time as they wish to prepare students for engineering positions beyond those associated with the more technologically dependent sectors of local industry. This might be seen as almost a 'double-compensation' policy for the faculty, - compensating first for an insufficiently technical pre-university environment, and, second, compensating for the lack of a very varied post-university work situation. In addition to these tasks, it would seem that a faculty might also want to prepare students to be able to work on feasible small scale technologies. Again a concern with 'appropriate' engineering technologies may not have been a feature of the traditional imported syllabus of many of the Anglophone universities of the region. In short, the pursuit of 'relevance' may point an engineering curriculum in several very different directions, arguably making the teaching more demanding than, say, a UK engineering course emphasising design. Quite how these tensions resolve themselves will probably differ from faculty to faculty, and within faculties, from civil, to chemical to mechanical engineering. But the resulting syllabuses are likely to reflect very differing views of the relationship between engineering education and technological capability in industry. It should perhaps be pointed out that adjusting the courses to the present realities of industry and engineering occupations does not necessarily mean an emphasis on repair and maintenance skills; it can expose the student to ways of significantly modifying and stretching technologies that will continue to be imported. To this extent, the student can participate in a development of indigenous technological capability even while modifying existing imported technology.

1. UNESCO, International congress on science and technology education for development, op. cit. pp 27-28.

In somewhat similar ways, university science courses will be pulled in several different directions, and in other parts of post secondary technological education, polytechnics, technical colleges, and institutes of science and technology will be faced with what are really political decisions about technical and scientific potential in the country concerned. Very little research has been completed in these areas, but it seems that researchers both inside and outside science and engineering faculties are beginning now to analyse some of the main issues, and to look behind the easy labels of 'appropriate', 'relevant', 'of international standing' to examine the political economy of training and subsequent occupation.

There will be an opportunity, accordingly, for researchers to sensitise planners about new relationships between training and utilisation, going beyond the older arithmetic of manpower planning. Indeed, any more sensitive measures and analyses of 'engineer', 'technologist', 'scientist', and 'technician' will prove to be very timely. Several countries, including Kenya and Tanzania, continue to be much exercised about their scientific and technical manpower. In fact, Kenya has just launched an update of its 1975 Survey of Scientists and Technicians, and Tanzania has just completed a directory of scientific personnel.[1] These necessarily use very broad-brush categories like 'scientist', but there is increasing interest in more qualitative measures. What for example is the significance of Kenya's having 5082 scientists and 5883 technicians in the 1975 survey? By December 1982 current figures will be available from the present survey, but interpreting the significance of the increase over a seven years period will be an important and complex task. In what kind of activity were the 1300 scientists in the private sector of the economy engaged in 1975? In what ways will the assumed numerical increase be matched by a qualitative increase in indigenous scientific capacity?

These and other issues are important as Eastern African countries plan further investment in higher technological capability. Kenya's proposed second university working party, for instance, found overwhelming

1. Utafiti: <u>Directory of scientific and technical potential of Tanzania</u> (Tanzania National Scientific Research Council, Dec. 1981)

support for an emphasis on science and technology in the new university. The report stressed the need for a major thrust in industrial policy towards the development of indigenous technology and the adaptation of what is imported. It would also be imperative to develop new and renewable energy resources. The role of the new university in achieving these ends is perhaps put rather too simply:

> In order to meet these objectives, it will be necessary to increase the production of technological manpower at the professional engineer, technician and craft levels. [1]

As we have seen, however, engineering and technology education is not an experience that has a single form, and it is possible there will be no very straightforward correspondence between the eventual courses and the attainment of this industrial transformation. Although science and technology education is widely hoped to have these consequences for industry, almost no analysis exists of how this does happen or how it might in the future.

4. Machine-building in East Africa

There is, nevertheless, an increasing number of calls for transformation towards the development of a capital goods industry in parts of Eastern Africa. The logic appears compelling; over 50% of a country's imports are likely to be machinery, transport equipment and manufactured goods. 'In the absence of machine tool building capabilities, the life line of industrial development of a country is highly dependent on imported machinery and its progress would not go beyond the stages of simple maintenance and repair of transport and agricultural machinery. Of course, the goal of even partial technology independence cannot be achieved without this basic industry because it forms the foundation for the development of other industries.'[2] The quotation is from a recent meeting in Kenya, but it would have been equally possible to have taken the reference from Tanzania where it has also been strongly argued that a machine tool complex should be started.[3]

1. Government of Kenya: Second university in Kenya: report of the presidential working party (Nairobi, Sept., 1981) pp. 40-41.

2. Govt. of Kenya: Industrial Sciences Advisory Research Committee: Report on the first national symposium on industrial research and development (Nairobi, Dec 1981), p. 21.

3. See von Mitschke-Collande, op. cit., pp. 73-85.

Whatever the merits of these proposals (and this is far from the ideal economic climate to be urging major long term investment in a capital goods sector), some attention has been given to the human resources side of the question. There is an awareness that, paralleling the difference between consumer and producer goods, there will be a qualitative difference in the skill and knowledge base required for this technological chance. Again, however, it seems that very little research has been done on the implications these proposals might have for the whole industrial training apparatus.

5. Education and Technology Planning

One of the problems of examining the potential for planning within and between education and technology is that both of these fields are in a somewhat fluid situation. The technology system with all the different bodies responsible for information gathering, decision-making and research is really only beginning to settle down in many countries, especially as the breakup of the East African Community has thrown back upon the individual governments many shared technology planning institutions. Other components in the total system such as Tanzania's Centre for Agricultural Mechanisation and Rural Technology (CAMART) have only just been formed.[1] In general, there are still major needs to connect the science training and research system with the technology application and production system.

Similarly in the education and training system, institutions have not really shaken down into a set of working relations with industry, agriculture and commerce. The boundaries of occupation are ill-defined, and there is no long tradition of institutions producing craftworkers, technicians or technologists. The absence of strong class and trade affiliations means that young trainees do not on the whole feel that they have received a level of training or education appropriate to their group. Aspirations continue at a high level throughout the region, and the fact that someone has received, say, a craft qualification is no bar to his or her attempting to enter further or higher education. This still shifting set of boundaries amongst institutions, occupation and

1. CAMART is formed from a merger of Tanzania Agricultural Machinery Testing Unit, and Arusha Appropriate Technology Project. See CAMART: 'Functional role and operational policy', Dar as Salaam, Ministry of Industries, April 1982, Mimeo.

status is intensified by the tendency for government to contemplate far-reaching changes in the training system. For example, after a little less than ten years in their present state, Kenya seems likely to abandon technical schools, and yet the whole rather fragile apparatus of apprenticeship was based on these four year secondary schools. If this part of the training system is altered, and if Kenya goes ahead with its intention of abolishing the 'A' level segments of many of their secondary schools, then it will have to absorb a shake-up of its education system more severe than is usually contemplated by stronger Northern industrialised nations.

Kenya possibly has a more major task of restructuring and absorbtion on hand than several of its neighbours. In addition to what has been mentioned, there is a further layer of self help institutes of science and technology that need to be related to particular levels of training and technology. There certainly seems then to be nothing very sacrosanct about the traditional pyramid of engineers, technicians and skilled workers. Vertical mobility is still very common in the lower two groups both in Kenya and elsewhere. For example, in Tanzania one of the unforeseen consequencies of changing the whole university entry system to allow for mature age candidates has been to encourage many technician level workers to seek university entrance (often successfully).

There is a further set of institutional complications at the artisan level. In all Eastern African countries there is a very significant informal training system, differentiated by status, income and type of industry. The "street-mechanic" training system is very widespread. and versions of it are to be found in most of the small towns in East Africa. Its cheapness and efficiency continue to make for grave difficulties of state planning of artisan education whether by the ministries of education or of labour. Indeed in Kenya the Directorate of Industrial Training has recently taken an interest in offering support directly to this alternative informal training system, but it is too early to observe any outcome. [1]

1. The DIT are currently looking at the possibility of supporting the Nairobi Organised Mechanics Association, a large garage-cum-training school for informal apprentices.

If there is to be improved planning of education in relation to technology there will be a need for a much more comprehensive mapping both of the training terrain as well as the various components of the technology system. Very little is really known about the structural relationships between new training institutions and particular changes in the production system. It is easy to assume in Eastern Africa that there is very little planned policy relation between, say, the emergence of a rash of harambee institutes of science and technology on the one hand and any specific alterations in industry or the technology system, on the other. Consequently, tracing the shifting contours of the training and technology institutions would be a timely task. The speed of certificate escalation in education and training would be an added reason for getting behind the many apparent fluctuations in technical and vocational policy.

Conclusion

In this short discussion paper, it has only been possible to mention a few of the issues that are emerging as areas of debate and study at the moment in some parts of Eastern Africa. Two countries were the source of much of the illustrative material, and obviously if, say, Zambia and Zimbabwe had been taken as the primary examples, the focus might have been substantially different, particularly given the wider constellation of local industrial capacity in Zimbabwe and the importance of the mining sector in Zambia. It would also have been quite possible to have looked hard and long at the role of science in university rather than school, and technology training in polytechnics rather than engineering at university. Equally, it could have been possible to concentrate on the rural rather than the urban sector, and examine the very complex relations amongst peasant technology, agricultural capability, and training systems at the degree or diploma level.

But the conclusion might have remained the same: that since the retreat from the manpower planning of the 1960s and early 1970s, there has been a failure analytically to make sense of the connections between education and the workforce. Part of that retreat stemmed from worries about the reality of work and qualification that might lie behind the numbers.

By contrast, new ways of connecting education and work are likely to be much more concerned about the quality of the job behind the title and the quality of skill and knowledge behind the qualification. New approaches are also likely to pay considerable attention to the role of national governments in setting education and technology policy, and the extent to which national options are limited by international economic forces on the one side and by popular perceptions of science, technology and education on the other.

But perhaps one of the greatest advantages of the new drive to analyse the nature of productive work and its preparation in developing countries will be a laying bare of how these separate systems are actually working. Instead of easy assumptions about the 'transformational potential of science', there may be more sense of what nine years of elite science can produce, - in attitude, method and application. It should also be possible to be more realistic about what science-for-everyone presently means and what it could mean. Framing declarations is important for galvanising the science and technology communities, but it is also vital to ponder precisely how science knowledge can become an inspiration in countries where resources and work are scarce, and where the majority may receive their science diluted by poor teaching, no materials, and by very major difficulties of transferring that knowledge to the improvement of their own situation.

We end with an example of the problem of that transfer of science to working life. The following is the best remembered piece of science knowledge from a boy with four years inadequate secondary education, and one and a half year's experience of tramping through an East African city in search of work:

Osmosis

If you can carry out an experiment to see how osmosis takes place, you will get a potato then cut a hole in it fill the hole with salt or sugar then put your apparatus on sunlight for times. After that you will find that the sugar or salt you had fill in a potato has turn in a liquid form.

While on sunlight as far as salt had difused in the potato, you will find that that potato is losing its water filling the hole you had cut in it.

NB
Note that the potato is boiled or is still raw or the two potatoes boiled and raw ones there will be a different about how the osmotic pressure takes place. To examine this experiments take the raw potato or both and place them in a dish of water and place salt or sugar in the cavity cut in the boiled potato, and also in the raw ones. After 30-40 minutes the cavity of the raw potato with salt in it will be full of fluid since, first of all the salt dissolves in the sap exuding from the damaged cellors of dead ones, and then the salt solution withdraws water by osmotic pressure. In the boiled one there will be no such accumulation as far as the semi-permeability is a property of living protoplasm. 1

This is a long way from transformation science and from the declarations about science and technology at Harare. But how typical might it be of the science knowledge of the unemployed?

1. Oral interview, September 1982.